CACHE COHERENCE PROTOCOLS ANALYZER

A tool for analyzing how different Snooping based Cache Coherence Protocols perform under varying workloads

15-618 SPRING 2017 FINAL PROJECT

KSHITIZ DANGE (KDANGE)

YASH TIBREWAL (YTIBREWA)

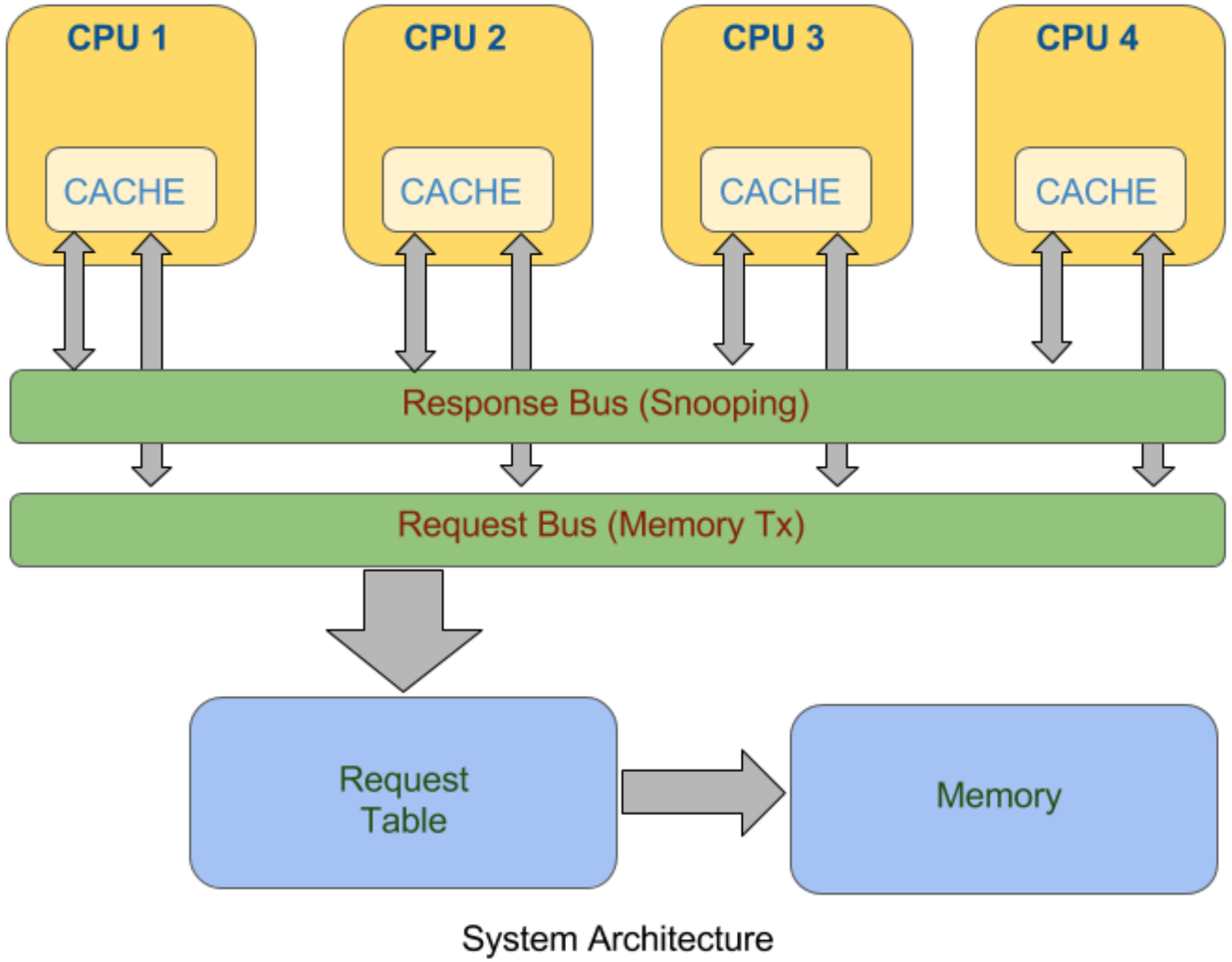
WHAT DID WE MAKE?

- Cache Simulator
  - Generate memory traces
  - Analyze the memory traces
    - Multiple snooping based cache protocol
    - Mimic real world system behavior

WHAT ARE WE TRYING TO SOLVE?

- Have a problem to solve
  - Need to design a system to solve it
    - What kind of cache coherence protocol can we use?
    - Our tool will help you decide!

SYSTEM DESIGN



System Architecture

PROTOCOLS

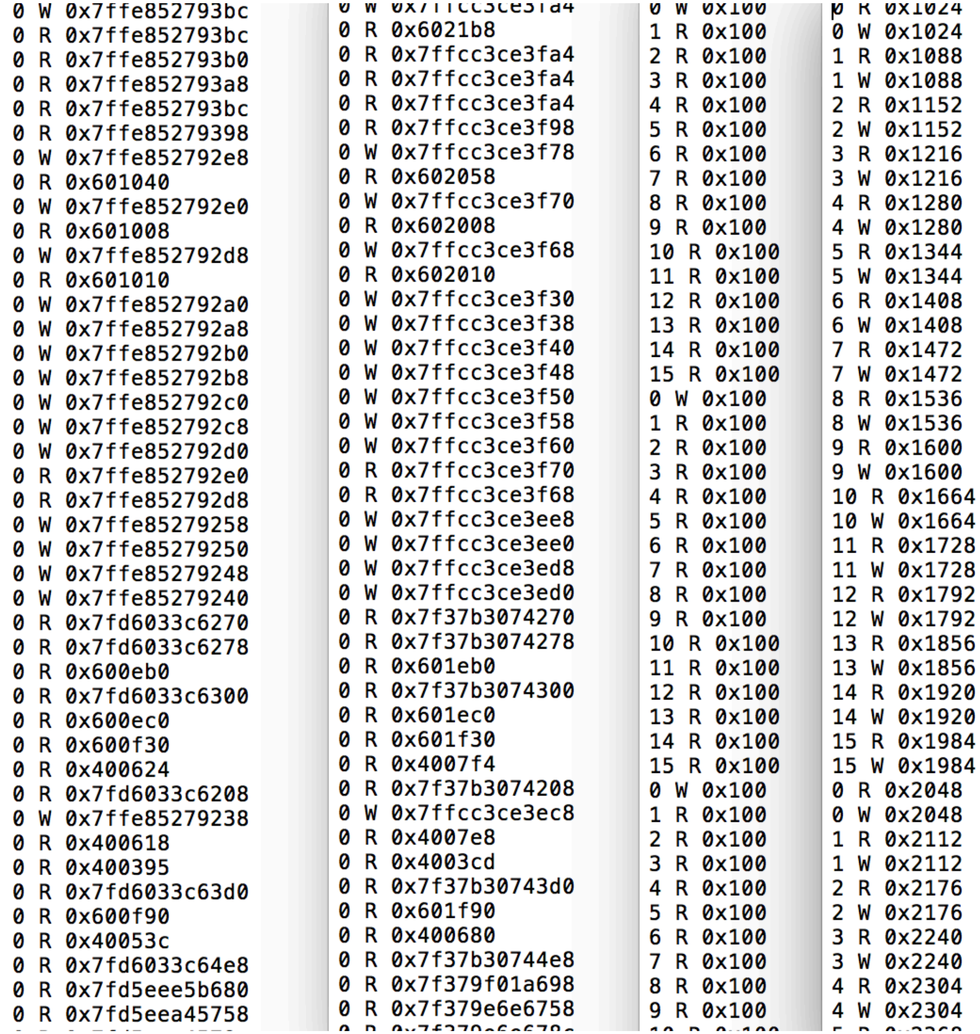
- Write Invalidate Protocols
  - MSI
  - MESI
  - MOSI
  - MOESI
- Write-Update Protocol
  - Dragon
- Hybrid Protocol
  - Competitive Snooping (!)

HOW DO WE COMPARE THE PROTOCOLS?

- Number of Bus Transactions
- Number of Memory Requests
- Number of Memory Write-Backs
- Number of Cache to Cache Transfers

HOW DO WE GENERATE THE MEMORY TRACE?

- Intel Pin-tool
  - Memory trace of a program
    - Problem?
      - Relevance of functions
      - HUGE!
    - Solution
      - Dummy functions



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0 W 0x7ffe852793bc
0 R 0x7ffe852793bc
0 R 0x7ffe852793b0
0 R 0x7ffe852793a8
0 R 0x7ffe852793bc
0 R 0x7ffe85279398
0 W 0x7ffe852792e8
0 R 0x601040
0 W 0x7ffe852792e0
0 R 0x601008
0 W 0x7ffe852792d8
0 R 0x601010
0 W 0x7ffe852792a0
0 W 0x7ffe852792a8
0 W 0x7ffe852792b0
0 W 0x7ffe852792b8
0 W 0x7ffe852792c0
0 W 0x7ffe852792c8
0 W 0x7ffe852792d0
0 R 0x7ffe852792e0
0 R 0x7ffe852792d8
0 W 0x7ffe85279258
0 W 0x7ffe85279250
0 W 0x7ffe85279248
0 W 0x7ffe85279240
0 R 0x7fd6033c6270
0 R 0x7fd6033c6278
0 R 0x600eb0
0 R 0x7fd6033c6300
0 R 0x600ec0
0 R 0x600f30
0 R 0x400624
0 R 0x7fd6033c6208
0 W 0x7ffe85279238
0 R 0x400618
0 R 0x400395
0 R 0x7fd6033c63d0
0 R 0x600f90
0 R 0x40053c
0 R 0x7fd6033c64e8
0 R 0x7fd5eee5b680
0 R 0x7fd5eea45758
```

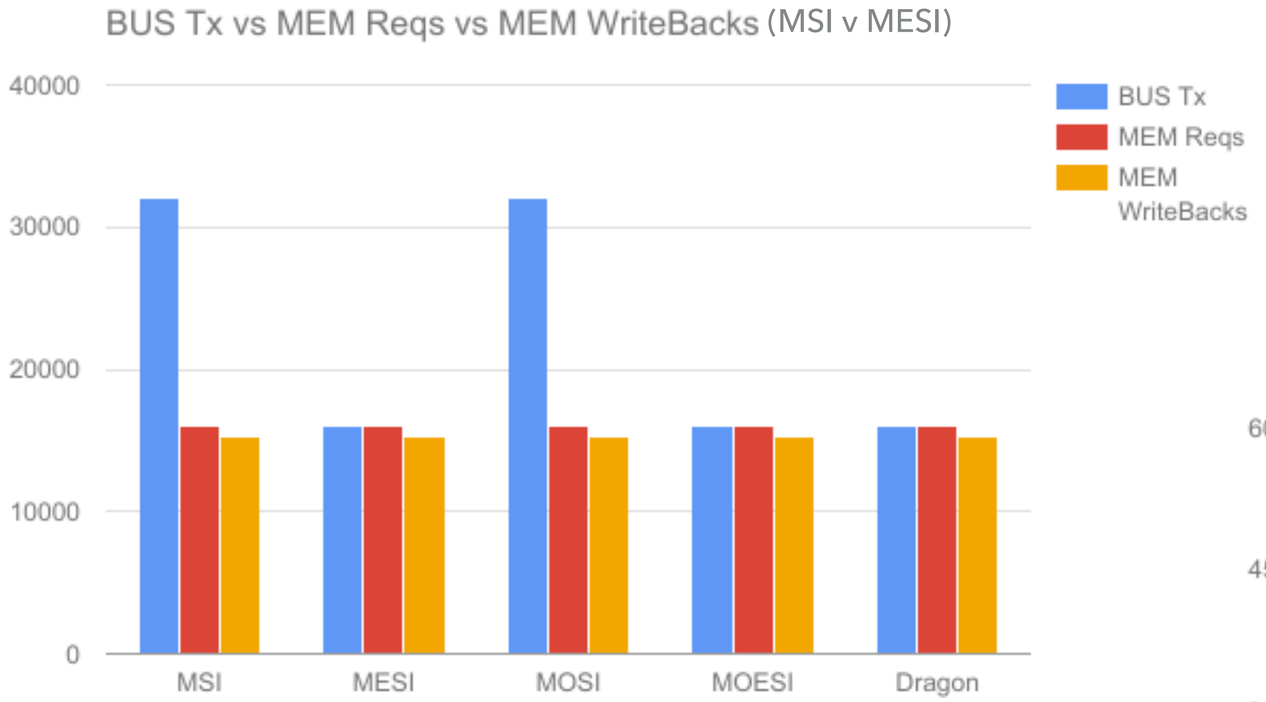
```
0 W 0x7ffcc3ce3fa4
0 R 0x6021b8
0 R 0x7ffcc3ce3fa4
0 R 0x7ffcc3ce3fa4
0 R 0x7ffcc3ce3fa4
0 R 0x7ffcc3ce3f98
0 W 0x7ffcc3ce3f78
0 R 0x602058
0 W 0x7ffcc3ce3f70
0 R 0x602008
0 W 0x7ffcc3ce3f68
0 R 0x602010
0 W 0x7ffcc3ce3f30
0 W 0x7ffcc3ce3f38
0 W 0x7ffcc3ce3f40
0 W 0x7ffcc3ce3f48
0 W 0x7ffcc3ce3f50
0 W 0x7ffcc3ce3f58
0 W 0x7ffcc3ce3f60
0 R 0x7ffcc3ce3f70
0 R 0x7ffcc3ce3f68
0 W 0x7ffcc3ce3ee8
0 W 0x7ffcc3ce3ee0
0 W 0x7ffcc3ce3ed8
0 W 0x7ffcc3ce3ed0
0 R 0x7f37b3074270
0 R 0x7f37b3074278
0 R 0x601eb0
0 R 0x7f37b3074300
0 R 0x601ec0
0 R 0x601f30
0 R 0x4007f4
0 R 0x7f37b3074208
0 W 0x7ffcc3ce3ec8
0 R 0x4007e8
0 R 0x4003cd
0 R 0x7f37b30743d0
0 R 0x601f90
0 R 0x400680
0 R 0x7f37b30744e8
0 R 0x7f379f01a698
0 R 0x7f379e6e6758
```

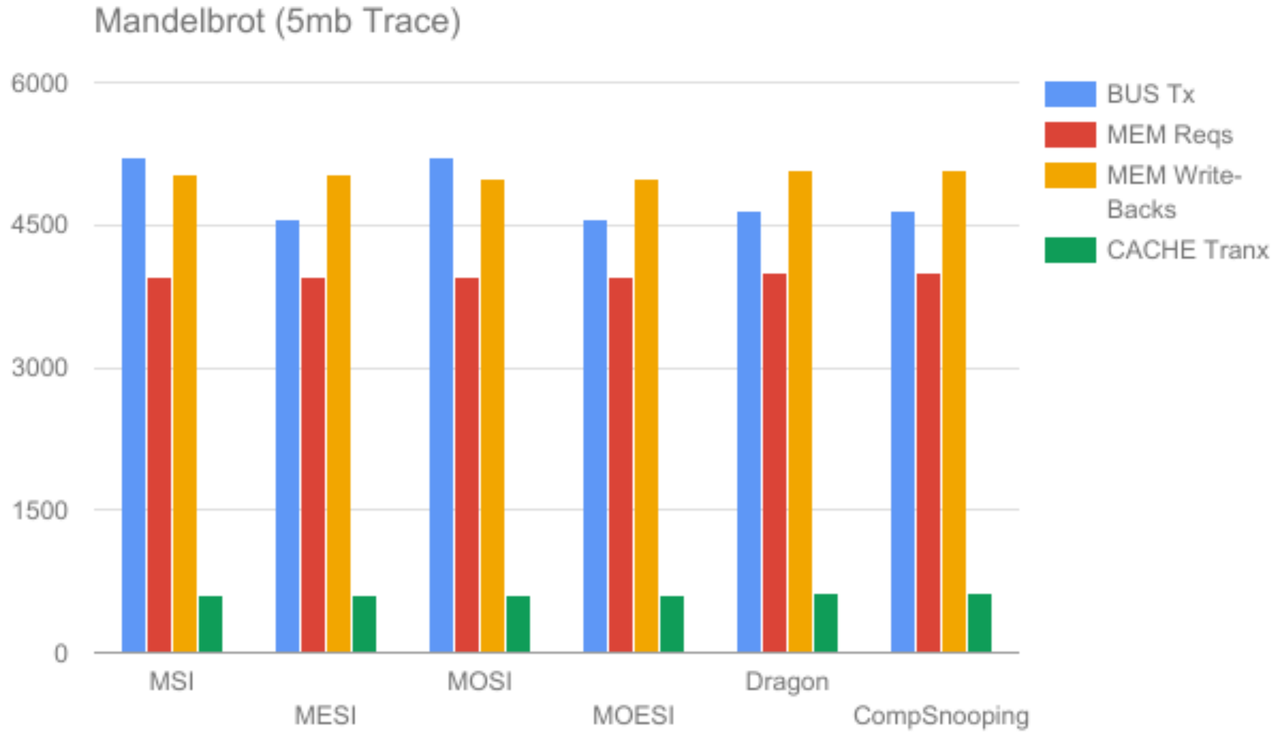
```
0 W 0x100
1 R 0x100
2 R 0x100
3 R 0x100
4 R 0x100
5 R 0x100
6 R 0x100
7 R 0x100
8 R 0x100
9 R 0x100
10 R 0x100
11 R 0x100
12 R 0x100
13 R 0x100
14 R 0x100
15 R 0x100
0 W 0x100
1 R 0x100
2 R 0x100
3 R 0x100
4 R 0x100
5 R 0x100
6 R 0x100
7 R 0x100
8 R 0x100
9 R 0x100
10 R 0x100
11 R 0x100
12 R 0x100
13 R 0x100
14 R 0x100
15 R 0x100
0 W 0x100
1 R 0x100
2 R 0x100
3 R 0x100
4 R 0x100
5 R 0x100
6 R 0x100
7 R 0x100
8 R 0x100
9 R 0x100
```

```
0 R 0x1024
0 W 0x1024
1 R 0x1088
1 W 0x1088
2 R 0x1152
2 W 0x1152
3 R 0x1216
3 W 0x1216
4 R 0x1280
4 W 0x1280
5 R 0x1344
5 W 0x1344
6 R 0x1408
6 W 0x1408
7 R 0x1472
7 W 0x1472
8 R 0x1536
8 W 0x1536
9 R 0x1600
9 W 0x1600
10 R 0x1664
10 W 0x1664
11 R 0x1728
11 W 0x1728
12 R 0x1792
12 W 0x1792
13 R 0x1856
13 W 0x1856
14 R 0x1920
14 W 0x1920
15 R 0x1984
15 W 0x1984
0 R 0x2048
0 W 0x2048
1 R 0x2112
1 W 0x2112
2 R 0x2176
2 W 0x2176
3 R 0x2240
3 W 0x2240
4 R 0x2304
4 W 0x2304
```

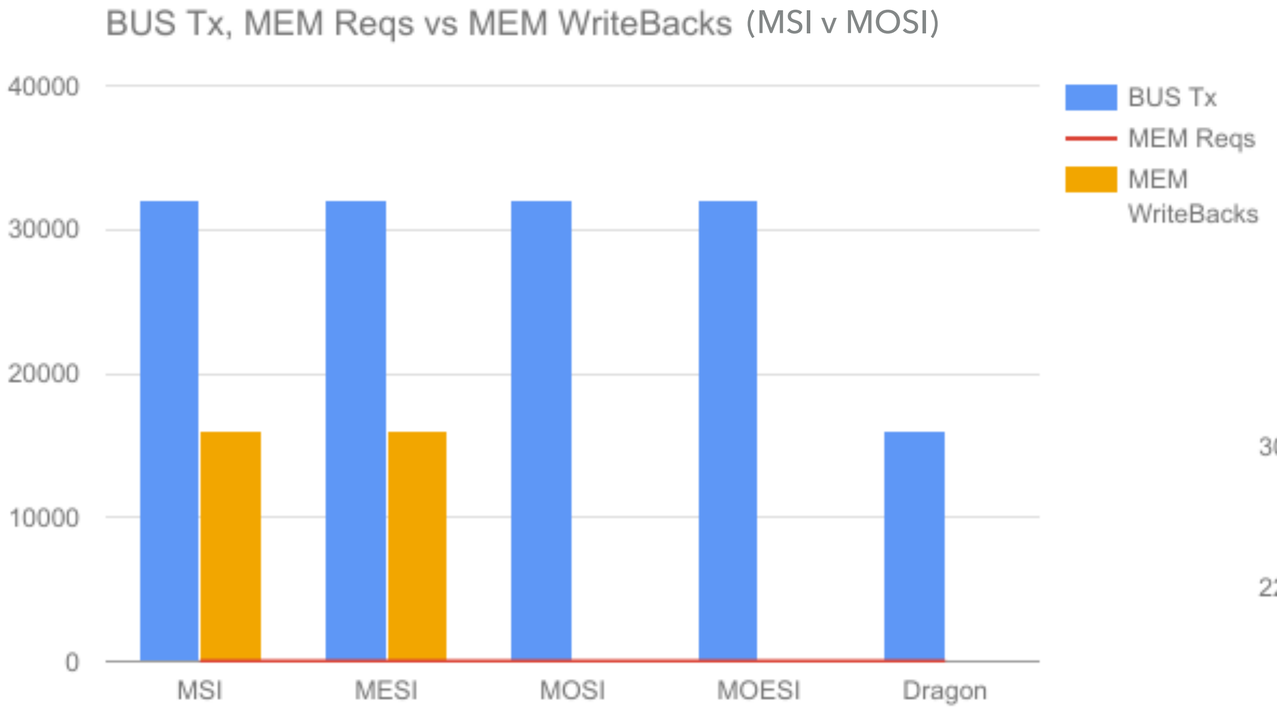
WHAT DID THE TOOL HELP US ANALYZE?

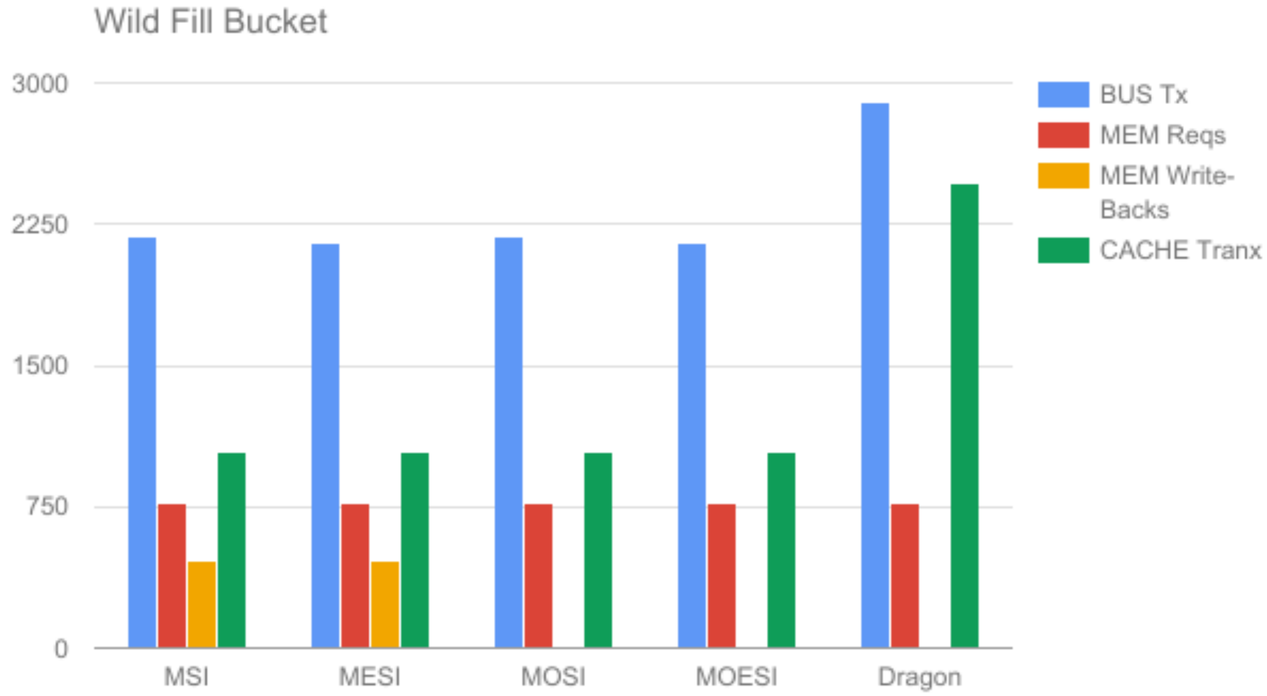
BENEFIT OF ‘E’ STATE



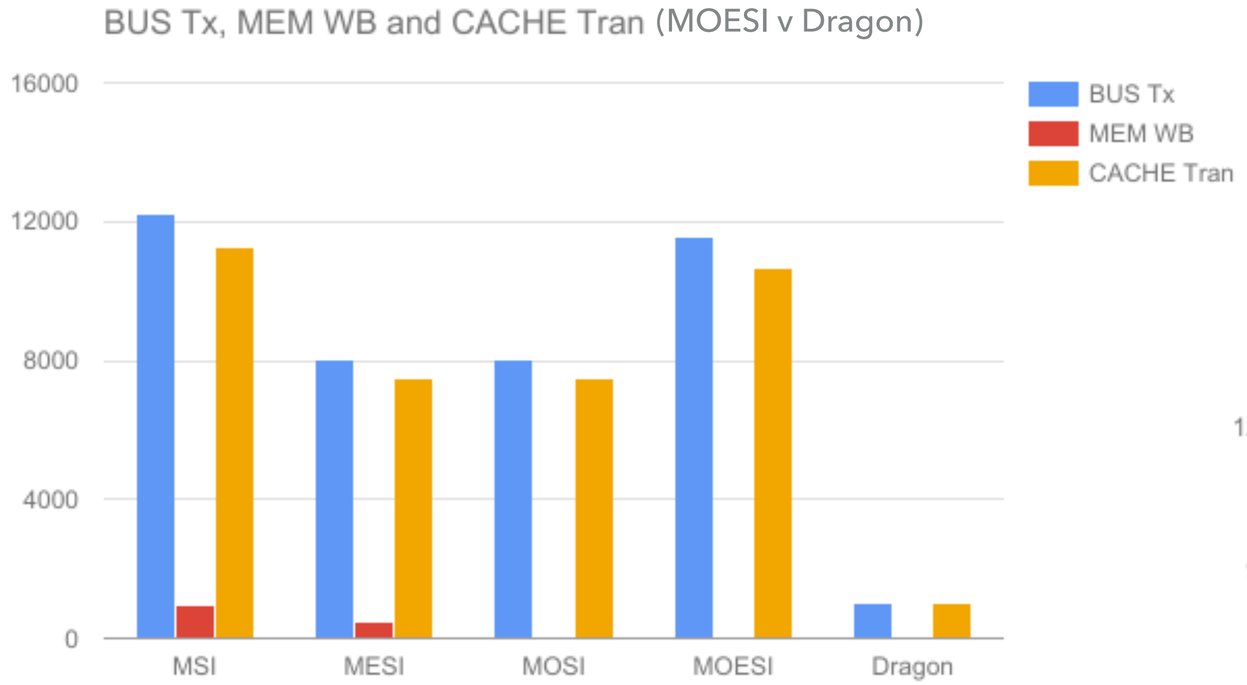


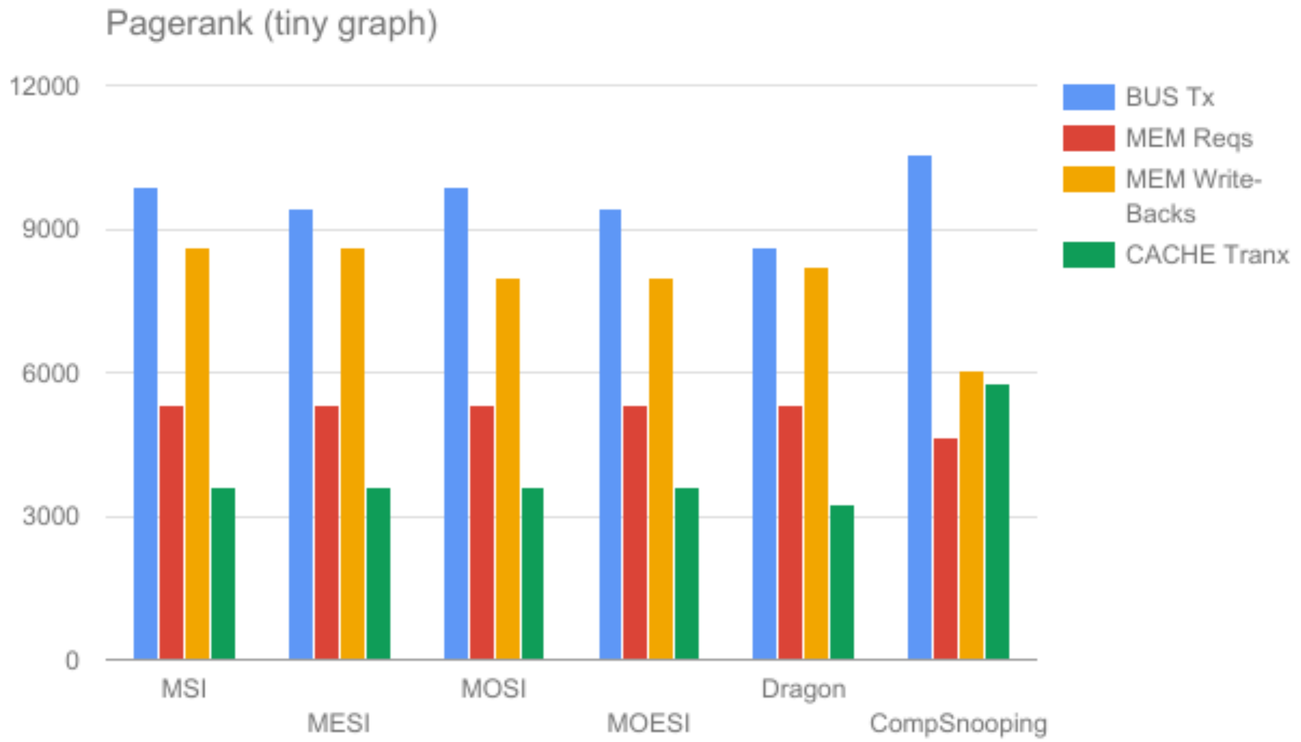
BENEFIT OF ‘O’ STATE



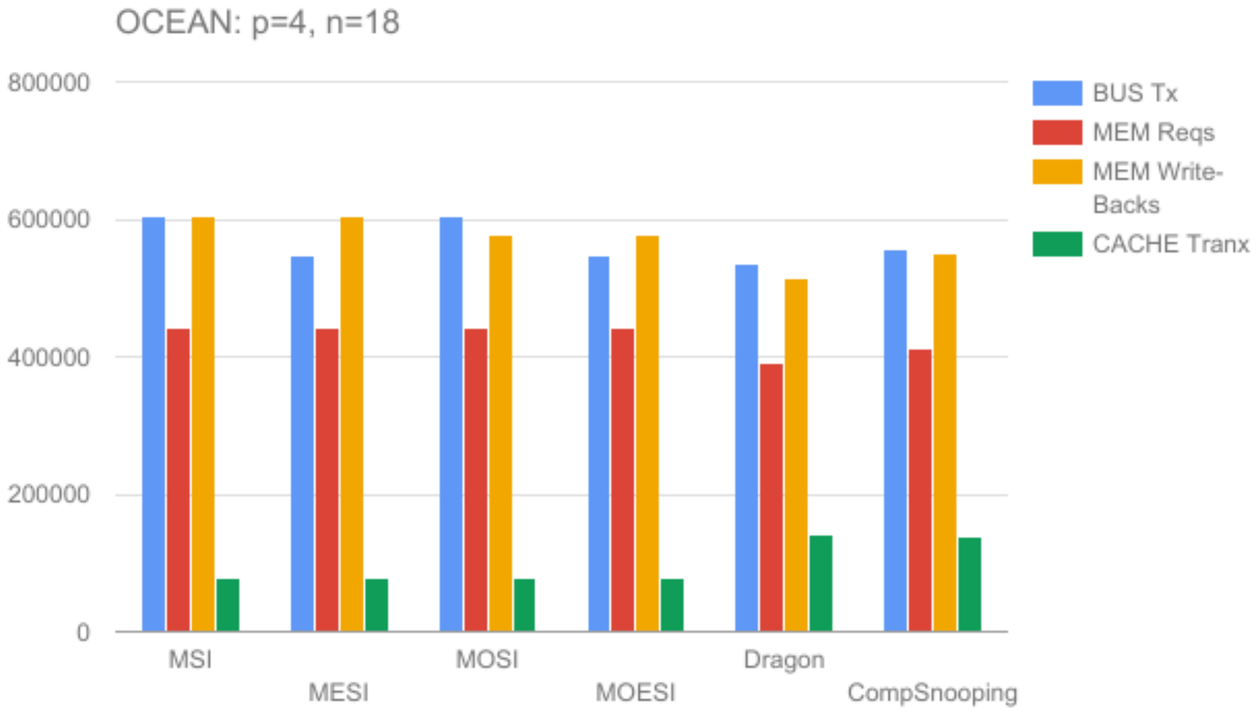


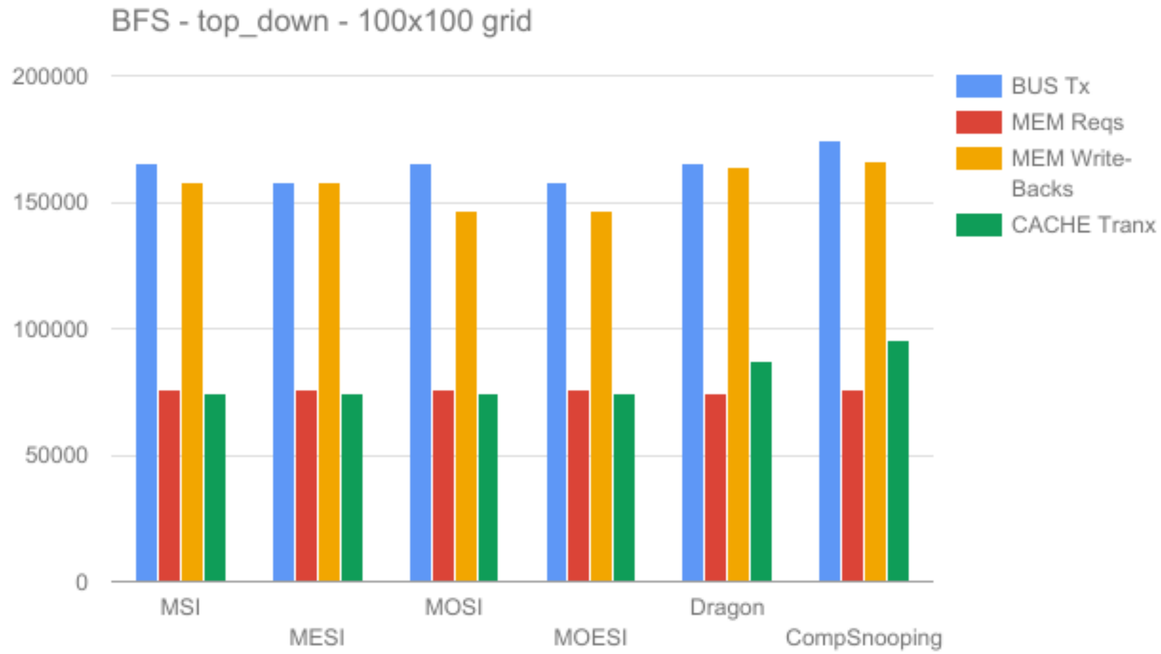
WRITE INVALIDATE vs WRITE UPDATE





COMPETITIVE SNOOPING (!)

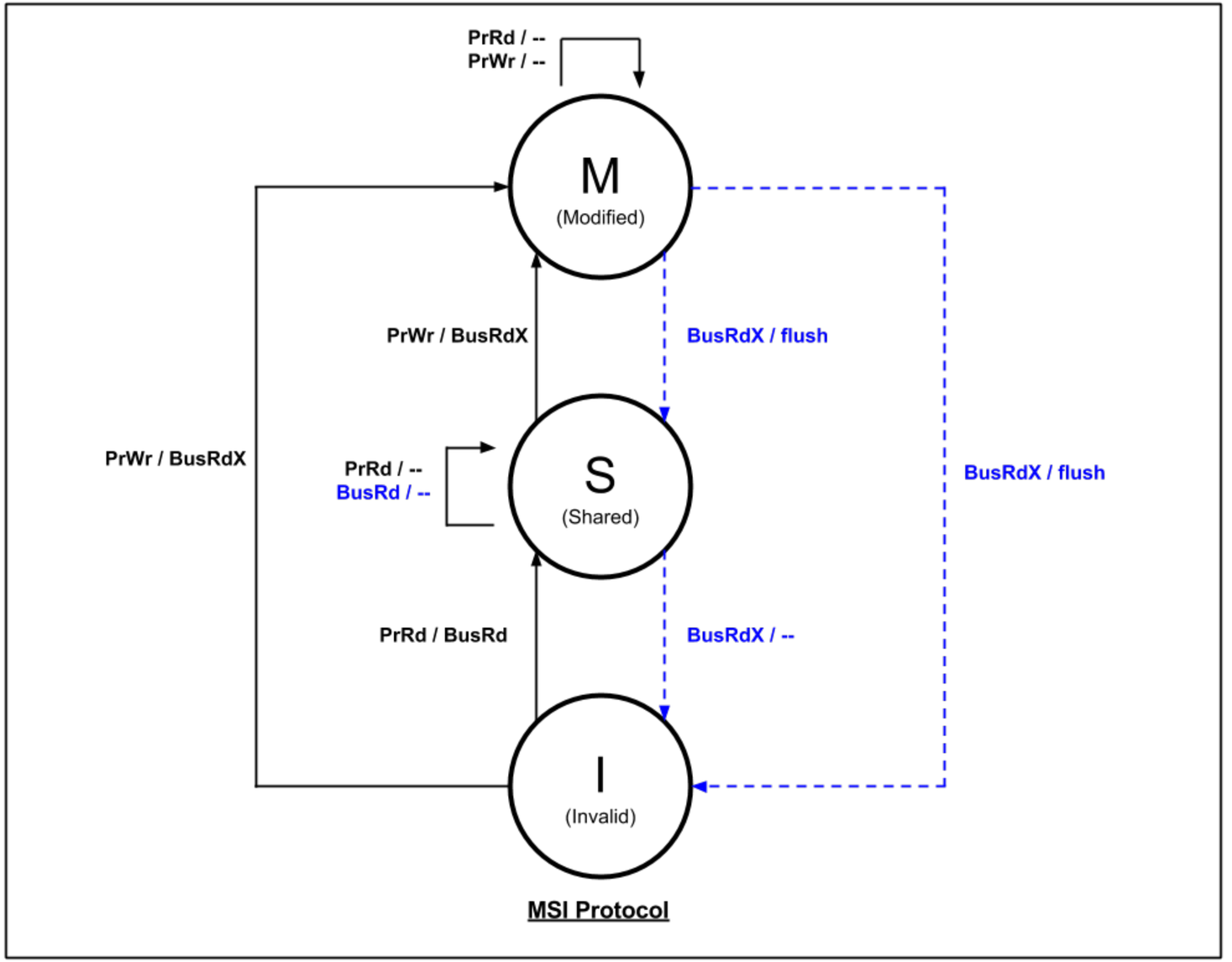


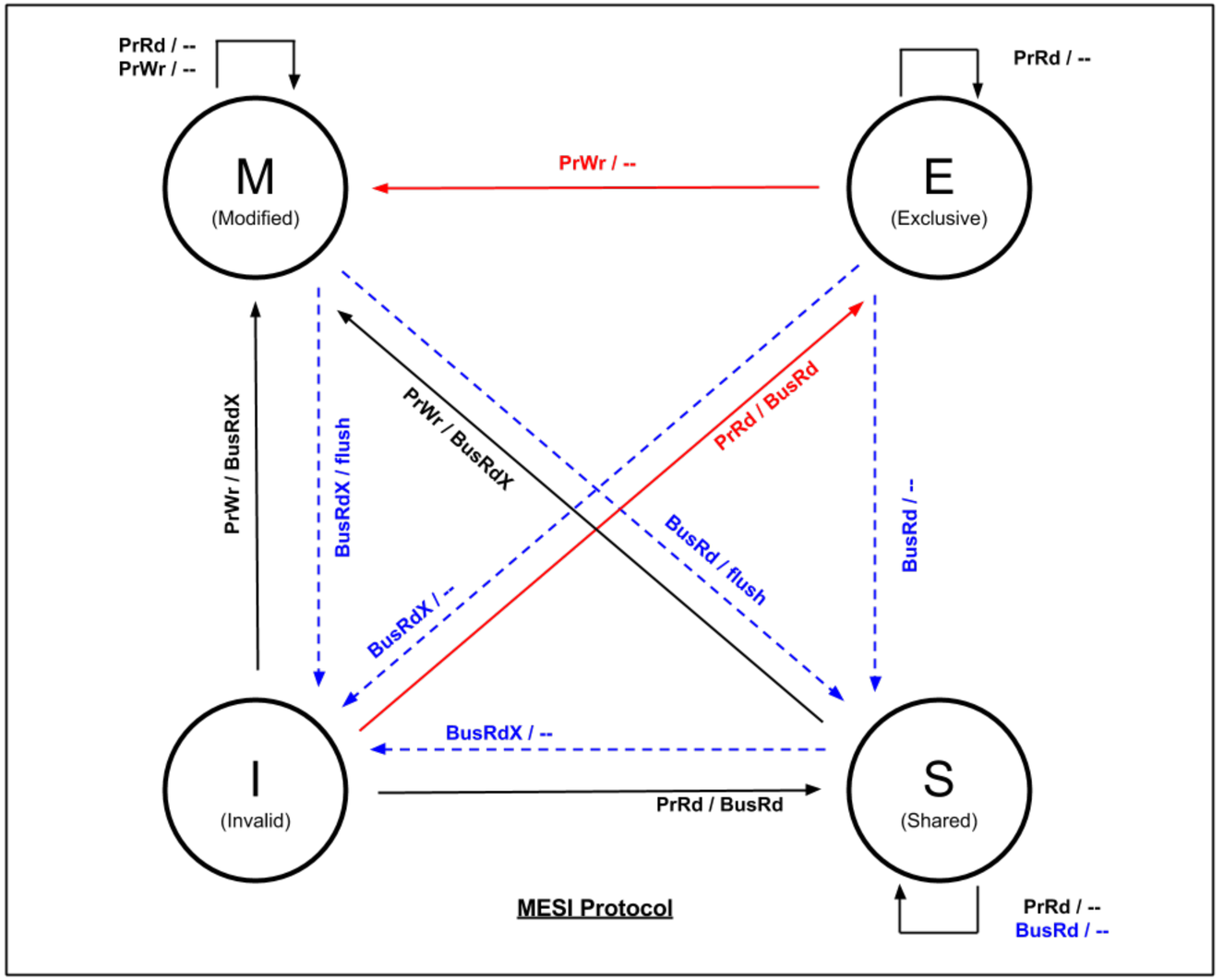


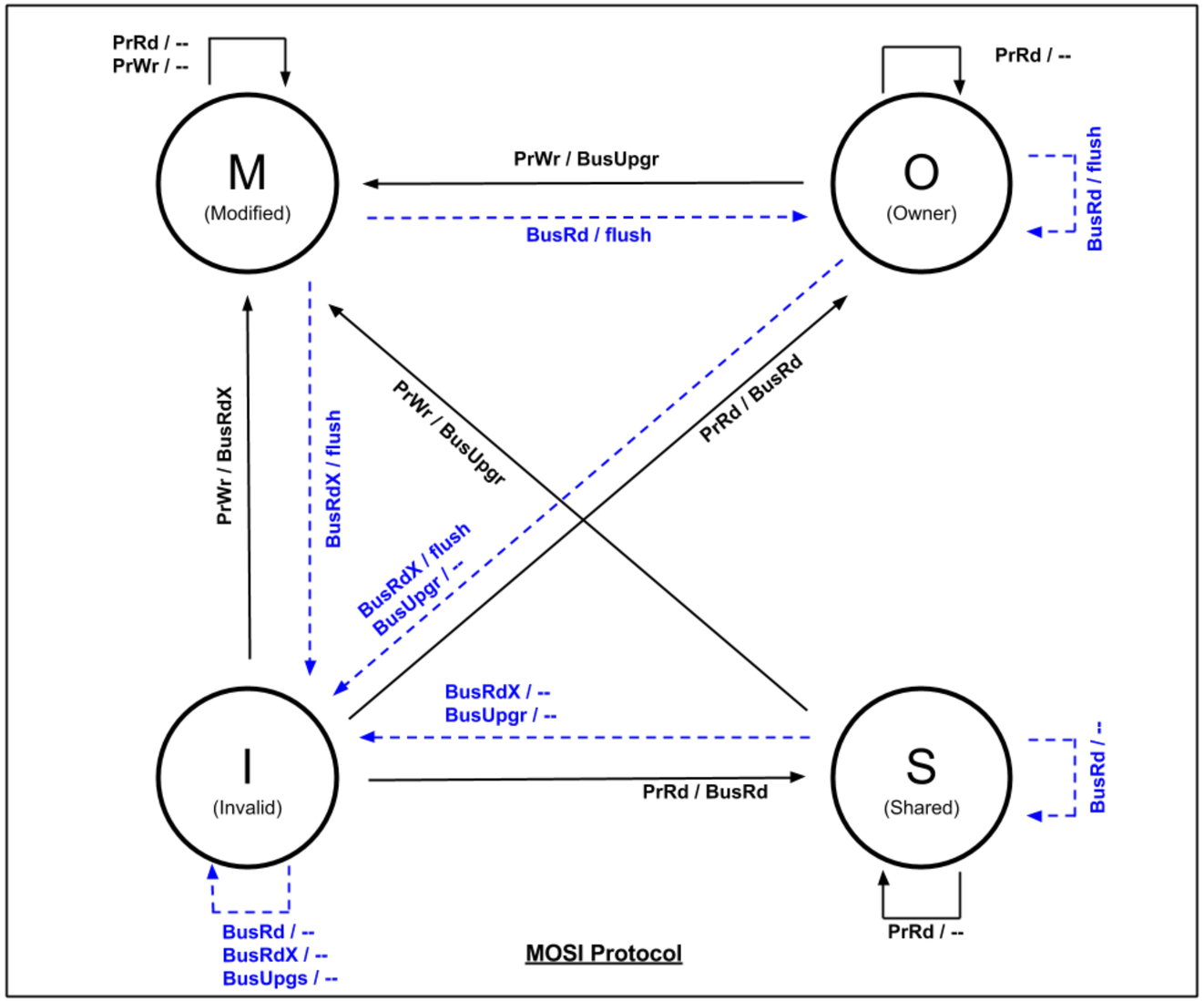
WHICH ONE WOULD YOU CHOOSE?

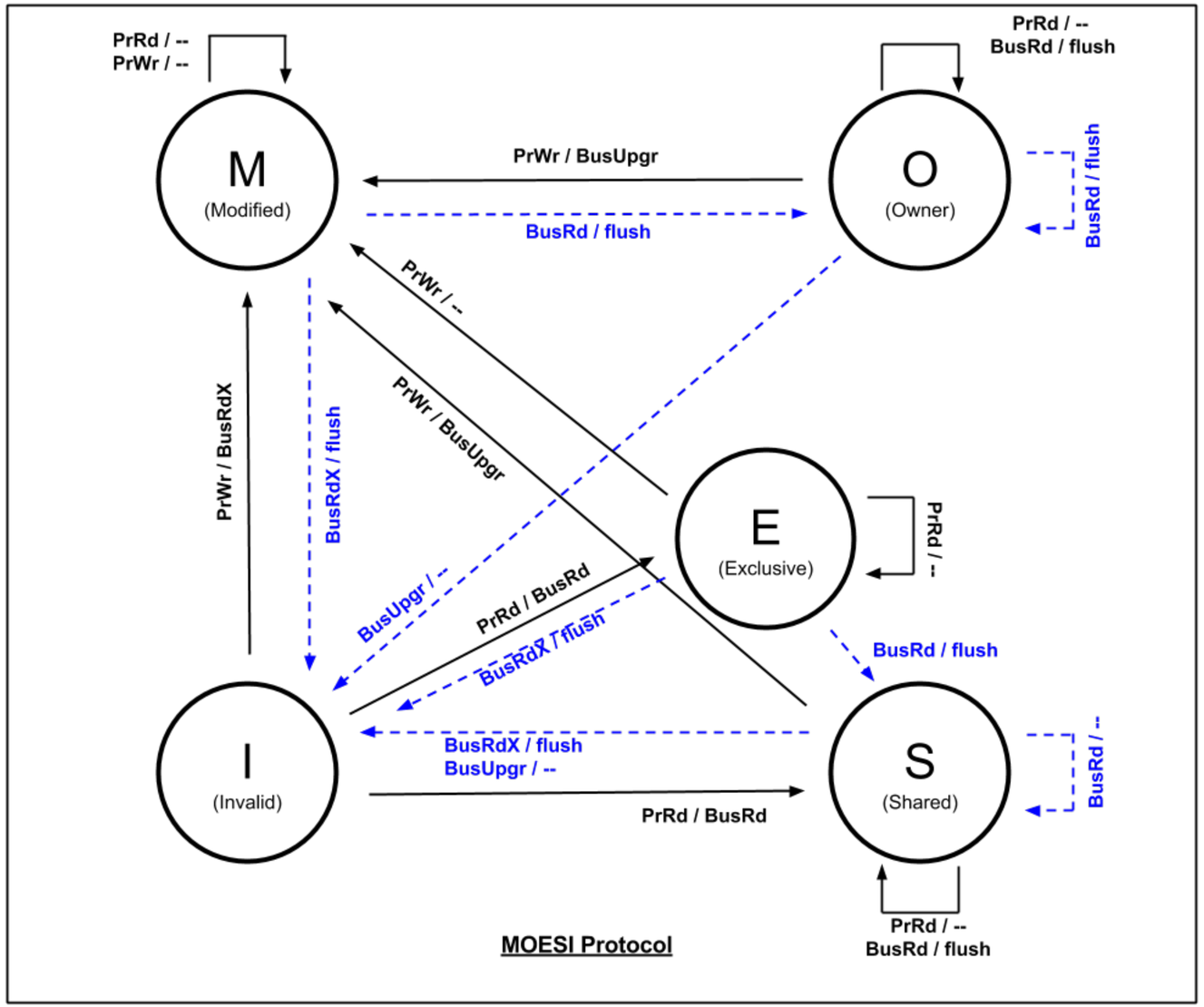
THANK YOU!

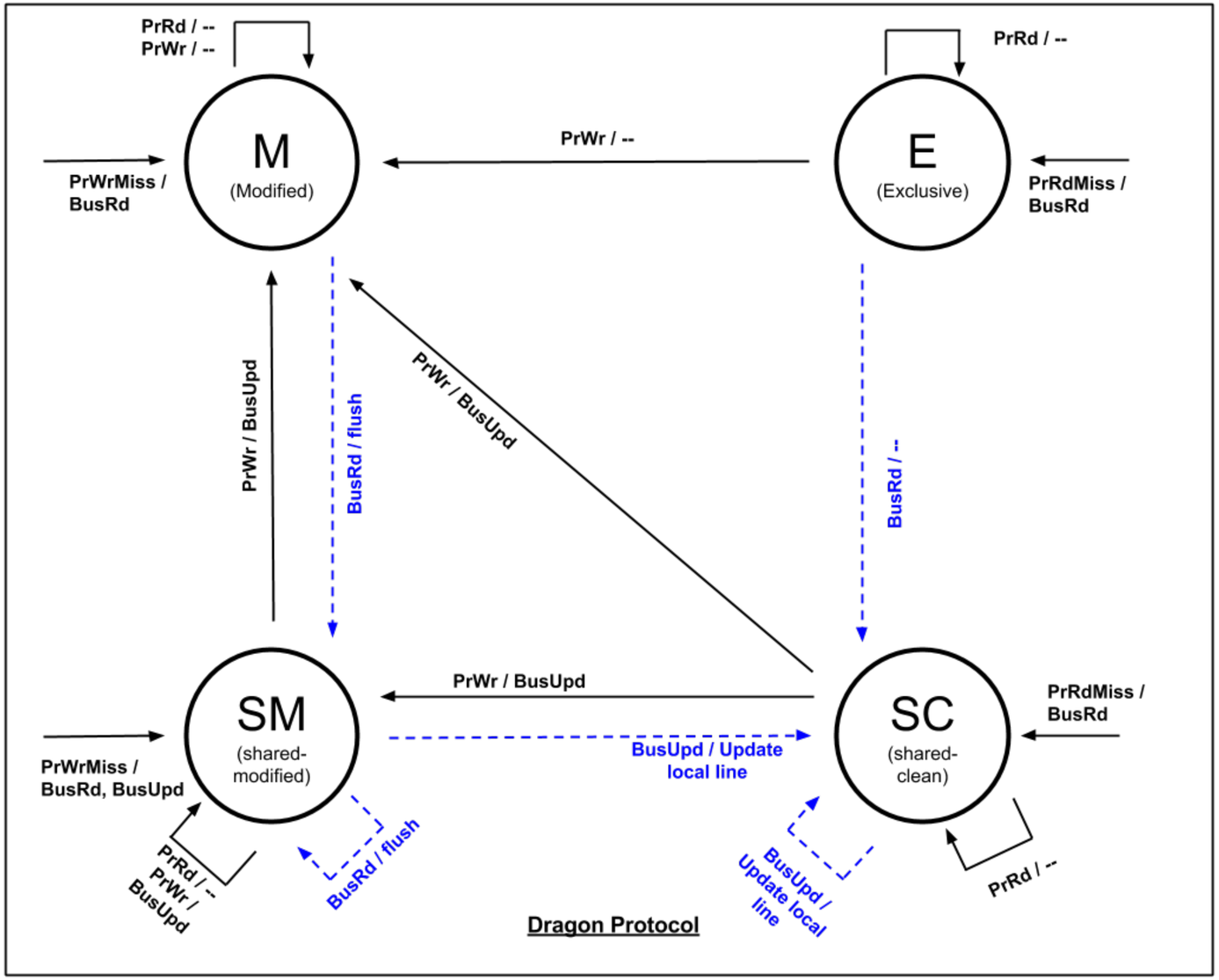
Kshitiz Dange and Yash Tibrewal


PrRd / --
PrWr / --
M
(Modified)
PrWr / BusRdX
BusRdX / flush
PrWr / BusRdX
PrRd / --
BusRd / --
S
(Shared)
BusRdX / flush
PrRd / BusRd
BusRdX / --
I
(Invalid)
MSI Protocol


PrRd / --
PrWr / --
M
(Modified)
PrRd / --
E
(Exclusive)
PrWr / --
PrWr / BusRdX
BusRdX / flush
PrWr / BusRdX
PrRd / BusRd
BusRd / flush
BusRd / --
BusRdX / --
BusRdX / --
I
(Invalid)
PrRd / BusRd
S
(Shared)
PrRd / --
BusRd / --
MESI Protocol


PrRd / --
PrWr / --
M
(Modified)
PrWr / BusUpgr
BusRd / flush
O
(Owner)
PrRd / --
BusRd / flush
PrWr / BusRdX
BusRdX / flush
PrWr / BusUpgr
PrRd / BusRd
BusRdX / flush
BusUpgr / --
BusRdX / --
BusUpgr / --
I
(Invalid)
PrRd / BusRd
S
(Shared)
BusRd / --
PrRd / --
BusRd / --
BusRdX / --
BusUpgs / --
MOSI Protocol


PrRd / --
PrWr / --
M
(Modified)
PrRd / --
BusRd / flush
O
(Owner)
PrWr / BusUpgr
BusRd / flush
BusRd / flush
PrWr / --
PrWr / BusRdX
BusRdX / flush
PrWr / BusUpgr
E
(Exclusive)
PrRd / --
BusUpgr / --
PrRd / BusRd
BusRdX / flush
BusRd / flush
I
(Invalid)
BusRdX / flush
BusUpgr / --
S
(Shared)
BusRd / --
PrRd / BusRd
PrRd / --
BusRd / flush
MOESI Protocol


PrRd / --
PrWr / --
M
(Modified)
PrWrMiss /
BusRd
PrWr / --
E
(Exclusive)
PrRd / --
PrRdMiss /
BusRd
PrWr / BusUpd
BusRd / flush
PrWr / BusUpd
BusRd / --
SM
(shared-
modified)
PrWr / BusUpd
SC
(shared-
clean)
PrRdMiss /
BusRd
PrWrMiss /
BusRd, BusUpd
BusUpd / Update
local line
PrRd / --
PrWr /
BusUpd
BusRd / flush
BusUpd /
Update local
line
PrRd / --
Dragon Protocol

HOW CAN YOU CONFIGURE OUR TOOL?

- You can:
  - Specify the Number of Cores
  - Specify the cache size
  - Specify the associativity of cache
  - Specify the program trace to analyze
  - Specify the snooping protocol to use